Progressing Environmental Health and Justice through GIS: Developing Lead Surveillance from Critical Spatial Analysis of Risk, Screening Rates, and Socioeconomic Hardship

Babu Gounder[1*]

[1] Healthy Regions & Policies Lab, Department Geography & GIS, University of Illinois Urbana-Champaign, Urbana, U.S.
*gounder2@illinois.edu

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Introduction

Despite decades of public efforts to eliminate lead poisoning, a half-million children in the U.S. continue to have elevated blood lead levels (BLL) above the CDC's reference value I surveillance (Bellinger & Bellinger, 2006; CDC, 2024). surveillance of high-risk areas for childhood lead poisoning conventionally relies on screening filters driven by housing age for lead paint and pipe exposure. Under a changing climate, lead exposure is projected to escalate through synergistic environmental pathways where lead increases in bioavailability, changes in toxicokinetics, and re-suspends from contaminated soil (Levin et al., 2020; Noyes et al., 2009; Soto-Jiménez et al., 2026). This study analyzes public, community-level data across Chicago's 77 community areas to develop a socio-spatial framework that integrates epidemiology, cartography, and socioeconomics to improve community surveillance.

Method

High-rate clusters of lead poisoning cases among children under six years old were detected using discrete Poisson-distributed spatial scan statistics in SaTScan, which captures risk unbounded by administrative borders (Kuldroff, 2005). To address rate instability caused by small populations, Empirical Bayes smoothing (EBS) was used for BLL screening rates. Spatial overlays were used to analyze disease clusters with screening rates, proportion of older homes, and the Intercity Hardship Index (IHI), which measures multidimensional socioeconomic challenges through dependents, income, poverty, unemployment, education, and crowded housing. This study draws on Critical Environmental Justice theory (CEJ), which conceptualizes the interconnection between spatial environmental exposures and intersectional socioeconomic hardships (Pellow, 2016).

Results

Statistically significant, high-risk clusters of lead poisoning were detected in Chicago's West and South sides (RR > 2.0). Spatial overlay analysis demonstrate that these clusters do not align with the highest EBS screening rates (>50%), or the greatest proportions of older homes. Instead, they show more spatial convergence with the top two quartiles of the IHI. From a policy perspective, high screening rates are desired in areas with higher risk. This spatial mismatch exposes screening blind spots, pointing to unmonitored environmental exposure. Supplementary analysis of recent data validates the longitudinal utility of this socio-spatial framework. Baseline findings of low cases, low screening rates, and high hardship index scores in the Far South Side of Chicago represented areas that became part of an expanded cluster in recent data. This confirms screening blind spots and the relevance of socioeconomic hardship indices for targeted screening.

Discussion and Conclusion

By integrating spatial clustering with CEJ, this study demonstrates that advanced spatial statistics are not always required for public health action. Spatial scans and cartographic overlay provide an implementable approach that overcomes data scarcity and cost restrictions with environmental sampling. The findings highlight that surveillance should incorporate multisource exposure risk by accounting for the spatial aspects of pollution burdens that intersect with multidimensional socioeconomic disadvantages of communities. This socio-spatial framework has direct implications for structurally reforming administrative screening filters, while demonstrating the value of cartographic maps and multilevel theories in mapping structural urban health disparities and reducing systematic underscreening. With these renewed approaches, public policies can improve population screening, attenuate lead poisoning, and achieve healthier and more just environments for children.

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